ASSESSMENT ON REWORK COSTS PROBABILITY OF HOUSING PROJECTS IN SRI LANKA

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Rework or rectification is a common phenomenon as well as a norm in the construction industry. It is recognized as an unnecessary effort of redoing an activity that was incorrectly implemented at the first time. This research is motivated by the increased attention given to the significant impact that rework costs have on cost performance. Therefore, the research investigates the rework costs involved in rectifying the defects and thereby develop a rework costs probability model for housing projects in Sri Lanka. A questionnaire survey was carried out together with a detailed analysis of documents. Statistical methods for eliciting probability distributions were used to analyse the data collected from 47 housing. Results of the non-parametric test; goodness-of-fit tests, revealed that generalized exponential distribution provided the best fit for the dataset. Findings of the study indicates 36 different types of more likely to occur in housing projects in Sri Lanka. On average the total rework cost as a percentage of cumulative work done value is found to be 0.92% in housing projects. Finally, the research proposes to use the developed probability model for rework costs to enable construction practitioners a quantitative risk assessment and competitive advantage in the cost performance.

Keywords: housing projects, probability, rework cost, Sri Lanka

INTRODUCTION

Rework refers to non-achievement of quality standards within the construction industry. Rework as defined by Love and Li (2000) as the unnecessary effort of re-doing a process or activity that was incorrectly implemented the first time. The impact of rework on construction organisation is significant. It can adversely affect an individuals', organisations' and project's performance and productivity (Love 2002). Abdul-Rahman (1995) agrees that an organisation's reputation and its profit margin can be affected because the cost of redoing a project that is not up to standard is high. The need to reduce costs and at the same time improve quality standards is mutually supportive for any project. If the building process must achieve the principle of doing things right the first time and every time, it should be appreciated that the occurrence of defects has a price.

To perform rational defect prevention, it is necessary to have knowledge about defects, their causes and associated costs (Josephson 1999). Mills, Love and Williams (2009) have revealed that the rework cost could be result as 0.4 % to as high as 26 % of the contract value. For example, a study by Burati, Farrington and Ledbetter

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(1992) in the UK revealed that the cost of defect rectification varies between 0.4% and 26.0 % of total project costs resulting in an average cost of 12.4 %. In a similar vein, Rhodes and Smallwood (2002) estimated the cost of rework in a construction project in South Africa to be 13% of the value of the completed construction. Another research in the UK, Egan (1998) reported that up to 30% of construction work is related to rework while in the USA the annual loss due to rework could be as high as US$15 billion for industrial construction.

With this notion in mind, the objectives of the research are to;

- Identify significant defects according to its frequency which aroused rework
- Identify the cost impact of defects against frequency of occurrence
- Analyse the rework probability

The research identifies frequency of defects, probability of rework costs for rectification of defects of residential buildings in the course of construction and defect liability period. For the purposes of this research, rework is defined as 'the unnecessary effort of redoing a process or activity that was incorrectly implemented at the first time'.

Rework and defects

The term 'defect' has been defined differently by researchers. It means the shortcomings in the design and construction practices for some of them, while to others; it implies the inadequacies that arise from normal wear and tear. Olanrewaju and Idrus (2010) indicate that design and construction defects are those that are caused due to wrong methods of construction, poor materials and bad labour practices. "A defect is a shortfall in performance occurring at any time in the life of the product, element or building in which it occurs (BRE Digest 268). It is also a departure from design requirements where these were not themselves at fault" (Douglas and Ransom 2013: 49). However, Table 1 shows that there has been recent increase in research on defects in the house building sector.

Another term that is commonly used is rework. Rework may be defined as the process by which an item is made to conform to the original requirement by completion or correction (Ashford 1992). Alternatively, rework is doing something at least one extra time due to non-conformance to requirements (Construction Industry Development Agency 1995). A broader definition of rework is unnecessary effort of redoing a process or activity that was incorrectly done the first time (Love and Edwards 2004). However, Hwang, Thomas, Haas, and Caldas (2009) emphasis that all these definitions share a common theme which is to redo work due to non-conformance with requirements or the occurrence of a defect.

RESEARCH METHODOLOGY

A quantitative approach was used as the main research approach to obtain the frequency of defect occurrence and observe the behaviour of the total rework costs associated with defects. A questionnaire survey along with document survey was implemented to improve the reliability of the data obtained. The questionnaire had four major focuses: general profile of the project which had defects, types of defects together with their frequency and rework costs associated with them. The respondents were asked to consider their experience in projects where they had defects and answer the questions given under the above four areas. In addition, participants were given the list of defects identified in the literature. Where it deviates from the literature findings participants were given the freedom to indicate their own options.

Table 1: Definitions of defects in various contexts (Rotimi 2013: 89)

Context of definition	Definition	Literature Sources
Wider construction environment	Wider construction environment	BRE (1990)
Wider construction	Non-fulfilment of intended usage environment requirements	Josephson and Hammarlund (1999)
House building environment	Failing or shortcoming in function, performance, statutory or user requirements of a building that manifests itself within the structure, fabric services and other facilities of the building.	Ilozor, et al. (2004)
House building environment	A final product that does not meet the required quality.	Kim, et al (2007)
House building environment	A component has a shortcoming and no longer fulfils its intended function.	Georgiou (2010)
House building environment	Breach of any mandatory requirement by builder or anyone employed by or acting for the builder.	NHBC (2011)
House building environment	Something that is unfinished, or an imperfection that is inadequate or causes failure.	Beattie (2011)

The study sample was selected based on snowball sampling method as there was tendency of the participants were reluctant to furnish some of the confidential information. The respondents based on their professions can be shown as follows; Projects Manager (24%), Quantity Surveyor (36%), Site Engineer (20%), Assistant Site Engineer (8%), Quality Assurance Engineer (4%), Assistant Manager, Costing (4%) and Chief Engineer (4%). The research participants had 5 to 20 years of work experiences in building construction sector. For the data analysis, details were obtained from building projects situated in Western and Southern provinces carried out by different contractors.

Data were collected from construction firms which have C3 to C7 grading and registered with Construction Industry Development Authority (CIDA) in Sri Lanka. Altogether 100 questionnaires were distributed among the potential respondents and 56 were returned resulting a response rate of 56%. During the data collection, a detailed questionnaire along with a semi-structured and open ended questions were included to improve the reliability of the data. The received questionnaires were undergone through a screening test in order to see whether the questionnaires were consisted with relevant and appropriate data for being used in data analysis. After the screening test 3 questionnaires were rejected due to lacking consistency and inappropriate data. After the screening process, a thorough document survey has been carried out as a reliability measure. It has been carried out by reviewing their actual rework costs records with the research participants in their workplaces in order to identify the level and standard of their rework costs recording procedures. After completing the document survey, another 6 questionnaires were dropped down as they have 4 of the research participants have refused to expose their cost records and other 2 due to low standards of rework costs records.

Quantitative data collected from the questionnaire and document survey where required were encoded using the Statistical Package for the Social Science (SPSS) v.20 and results were analysed using both descriptive and inferential statistics. Additionally, EasyFit Professional 5.6 were used to analyse the probability of distribution of rework costs.

RESEARCH FINDINGS AND DISCUSSION

Frequency of defects occurrence

Total of 47 questionnaires have been received from the building type of housing where their project amounts ranging from 2 to 20 million Sri Lankan rupees, and Figure 1 depicts the responses given by the participants to the research. When considering the frequency of occurrence, defects which had not less than 5 occurrences, honeycombs, bulging of beams, level issues of slabs, bulging of columns, verticality issues of walls, plaster cracks, foundation defects, fading of paint and roof defects can be identified.

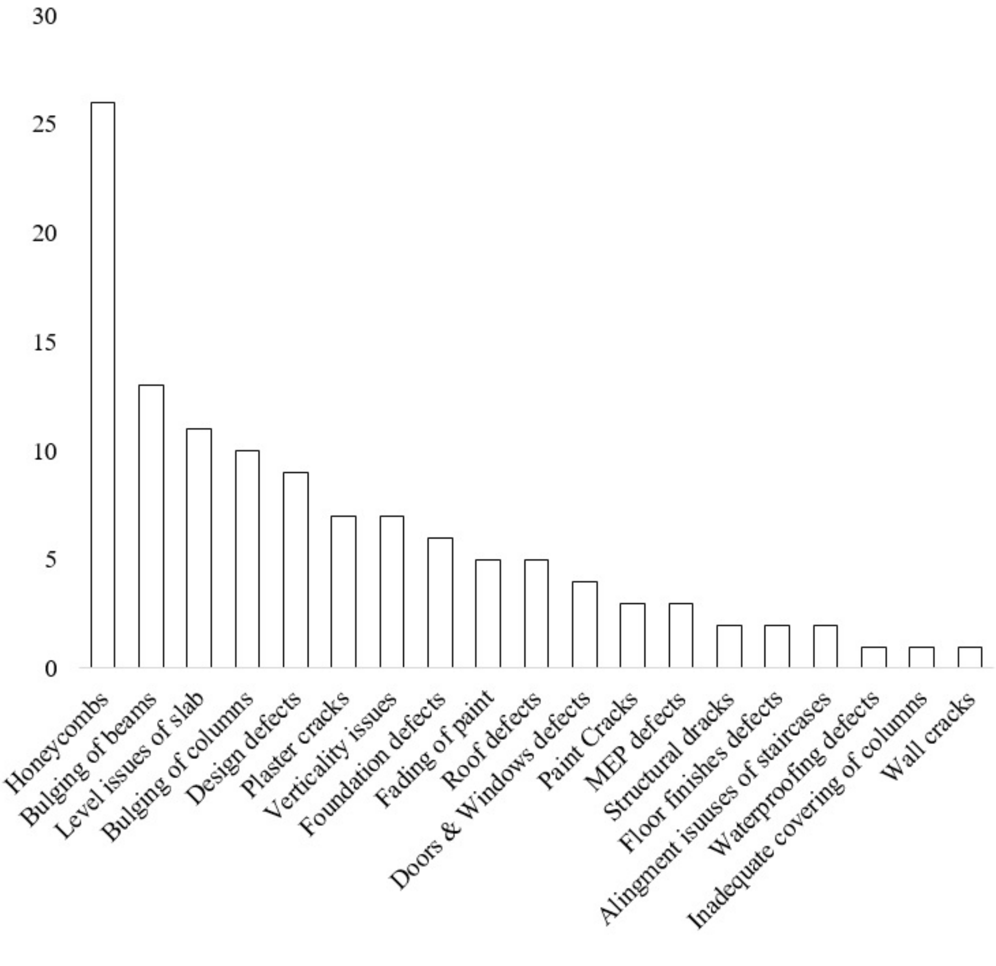

Figure 1: Frequency of occurrence

Honeycombs being the first in the ranking, are recognised as an unavoidable defect by the respondents. Due to this reason, some of them are not willing to admit it as a defect rather than a natural incident in the construction other than any major or severe honeycombs occurred, for instance honeycombs which arise into a deficiency in structural strength. As shown in Figure 2, frequency of defects and the impact on the total rectification/ rework cost by the defects can be analysed. The impact has been captured in accordance with the data provided by the respondents, and each rework/ rectification cost pertaining to a particular defect has been inserted into the questionnaire Likert scale by considering the respective percentage.

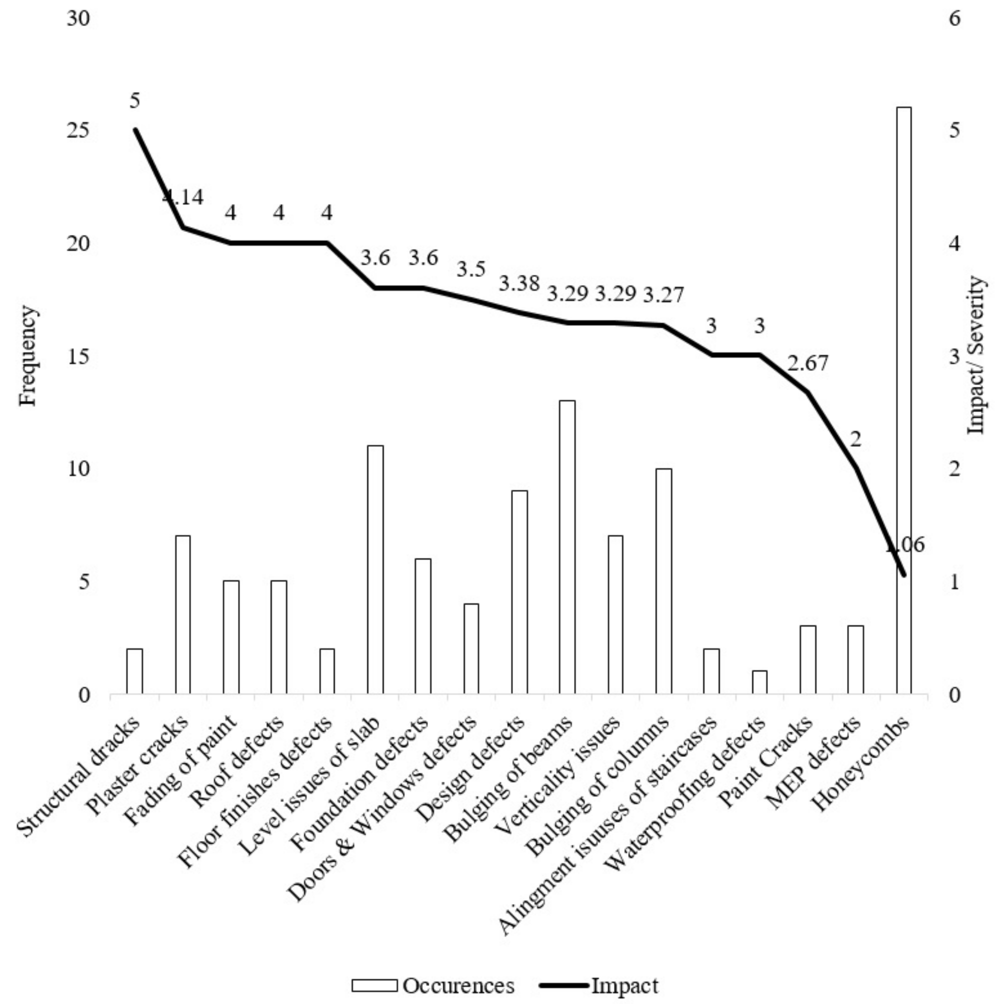

Figure 2: Impact on total rectification costs of defects

Subsequently, mean of Likert scale values graphed against the frequency to derive the Figure 2. It has to be noted that though honeycombs being the highest frequent defect among the defects, when considering the impact on the rectification costs it has scored the last. This graph depicts the defects which are of more significant in terms of cost irrespective of the frequency.

Rework costs

Table 2 presents the descriptive statistics for the total rework costs used in determining the probability of rework in the sampled project. The mean total rework cost as a percentage of the original contract sum was revealed to be 0.91% and the standard deviation was 0.86%. The data indicate that the total rework costs ranged from 0.05% to 3.7%. Evidently, the total costs of rework vary considerably among projects. It has been argued that the degree of variability in the estimates specified by the respondents suggests that many respondents may be unsure about the actual costs of rework incurred in the projects (Love 2002).

The following steps were adopted to determine the probability of rework. First, the probability density functions (PDFs) were developed using EasyFit Professional 5.6 software. The PDF is a mathematical expression that analyses a continuous random variable and defines the shape of the distribution. The 'best fit' probability distribution was examined using Kolmogorov-Smirnov and Anderson-Darling goodness-of-fit tests.

Table 2: Descriptive statistics of total rework costs

Statistic	Value	Percentile	Value
Sample Size	47	Min	0.049
Range	3.646	5%	0.0956
Mean	0.92	10%	0.122
Variance	0.74	25% (Q1)	0.583
Std. Deviation	0.86	50% (Q2)	0.583
Coeff. of Variation	0.94	75% (Q3)	1.292
Std. Error	0.13	90%	2.229
Skewness	1.32	95%	2.766
Excess Kurtosis	1.34	Max	3.695

Kolmogorov-Smirnov statistic (D): Based on the largest vertical difference between the theoretical and empirical CDF (Cumulative Distribution Function). Anderson-Darling statistic (A2): A general test to compare the fit of an observed CDF to an expected CDF. The test provides more weight to distributions tails than the Kolmogorov-Smirnov test. As observed from Table 3, the results of the goodness-of-fit tests revealed that generalised Exponential distribution provided the best fit for the dataset for total rework costs.

Table 3: Goodness-of-fit details for total rework costs

Kolmogorov-Smirnov					
Sample Size	47				
Statistic	0.072				
P-Value	0.953				
Rank	3				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.153	0.175	0.194	0.217	0.233
Reject?	No	No	No	No	No

Anderson-Darling					
Sample Size	47				
Statistic	0.072				
P-Value	0.953				
Rank	3				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.153	0.175	0.194	0.217	0.233
Reject?	No	No	No	No	No

The histogram presented in Figure 4, depicts probability distribution function for rework costs based upon the distribution parameters. For instance, Figure 4 shows that likelihood that a project will exceed a mean total rework cost of 0.92% is 37%.

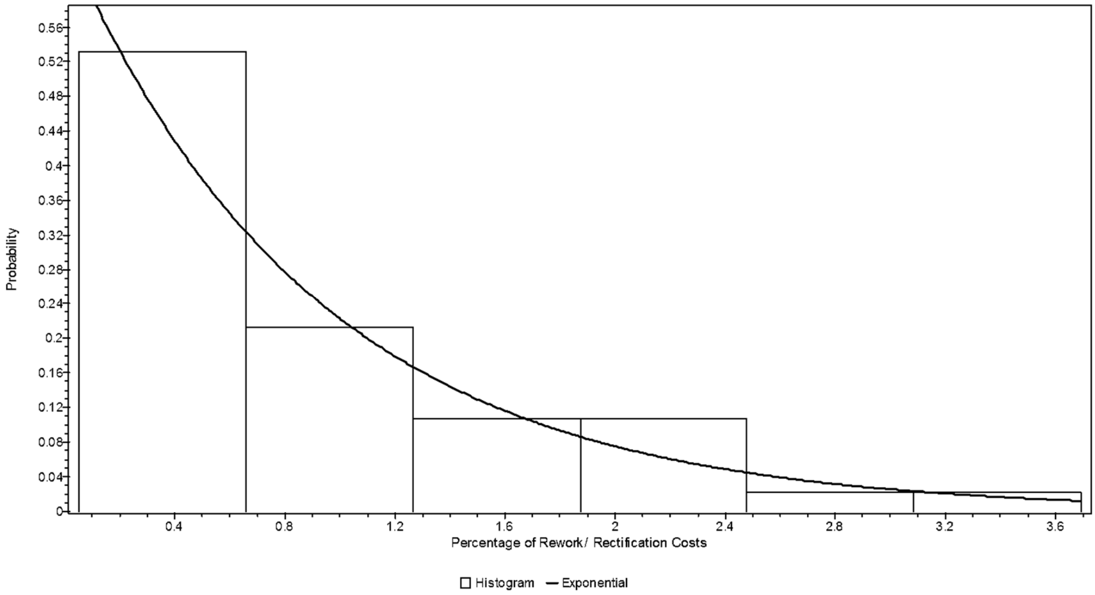

Figure 4: An exponential histogram of rework

DISCUSSION

Previous research studies done in several countries such as United Kingdom, United States of America, South Africa, etc. the rework costs have been turned out to be ranging from 0.4% to 30% of the project sum. In contrast to that this research has revealed that rework cost of house construction projects in Sri Lanka is being ranging from 0.5% to 3.7% of the project sum. Likelihood model of the rework cost has been developed in this research so it can be interpreted to see whether how much risk is involved against the project sum. For instance, when a domestic contractor is in the bidding process for a housing project, that contractor can use this probability model to determine the risk factor for rework over the others who may use other general high figure. In that scenario, knowing that the rework percentage is low when it comes to risk allowance in bidding for house construction projects in Sri Lanka, is a big advantage which can be drawn out from the probability model introduced in this research. As well, this research reveals the cost significance of defects against its frequency of occurrence, which may ultimately be focussed towards quality control of construction.

CONCLUSIONS

The research presented the types of defects and its frequency of occurrence during the course of construction and throughout the defect liability period. Required data from 47 housing projects were obtained through questionnaire survey along with interviews and document survey.

Research has uncovered most occurring defects types during construction and throughout the defect liability period. Considering the findings presented in this research, approximately 54% of the defects have been recorded in the concrete works during the structure construction. Most of the roof defects are due to water leakages and they were only reported within the defect liability period. As an overview, contribution factors for defects have been identified as lack of supervision, unfavourable working conditions, design errors, poor coordination of works, construction materials and poor workmanship. However, it was revealed that there was a lacking procedure in documentation and proper management of defects of most of the sites from the interviews conducted. As identified in the research, organizational practices have more influence on this aspect, as being some have established quality objectives to control defects and some have not had much consideration on defects.

The analysis of rework costs revealed that, the total rework costs as a percentage of the total work done value varies from 0.5% to 3.7%. During the statistical analysis, using Kolmogorov-Smirnov statistic and Anderson-Darling statistic, it has been observed the distribution of rework costs follows general Exponential distribution. The mean total rework cost as a percentage of the cumulative work done value was found to be 0.92%. For a mean total rework cost of 0.92%, the likelihood that a project exceeds is 37%.

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